PHASE CHANGE MATERIALS

PHASE

A phase is a set of states of a macroscopic physical system that have relatively uniform chemical composition and physical properties (i.e. density, crystal structure, index of refraction, etc).

PHASE CHANGE

A phase change is the transformation of a thermodynamic system from one phase to another. The distinguishing characteristic of a phase transition is an abrupt change in one or more physical properties, in particular the heat capacity, with a small change in a thermodynamic variable such as the temperature.

PHASE CHANGE MATERIALS

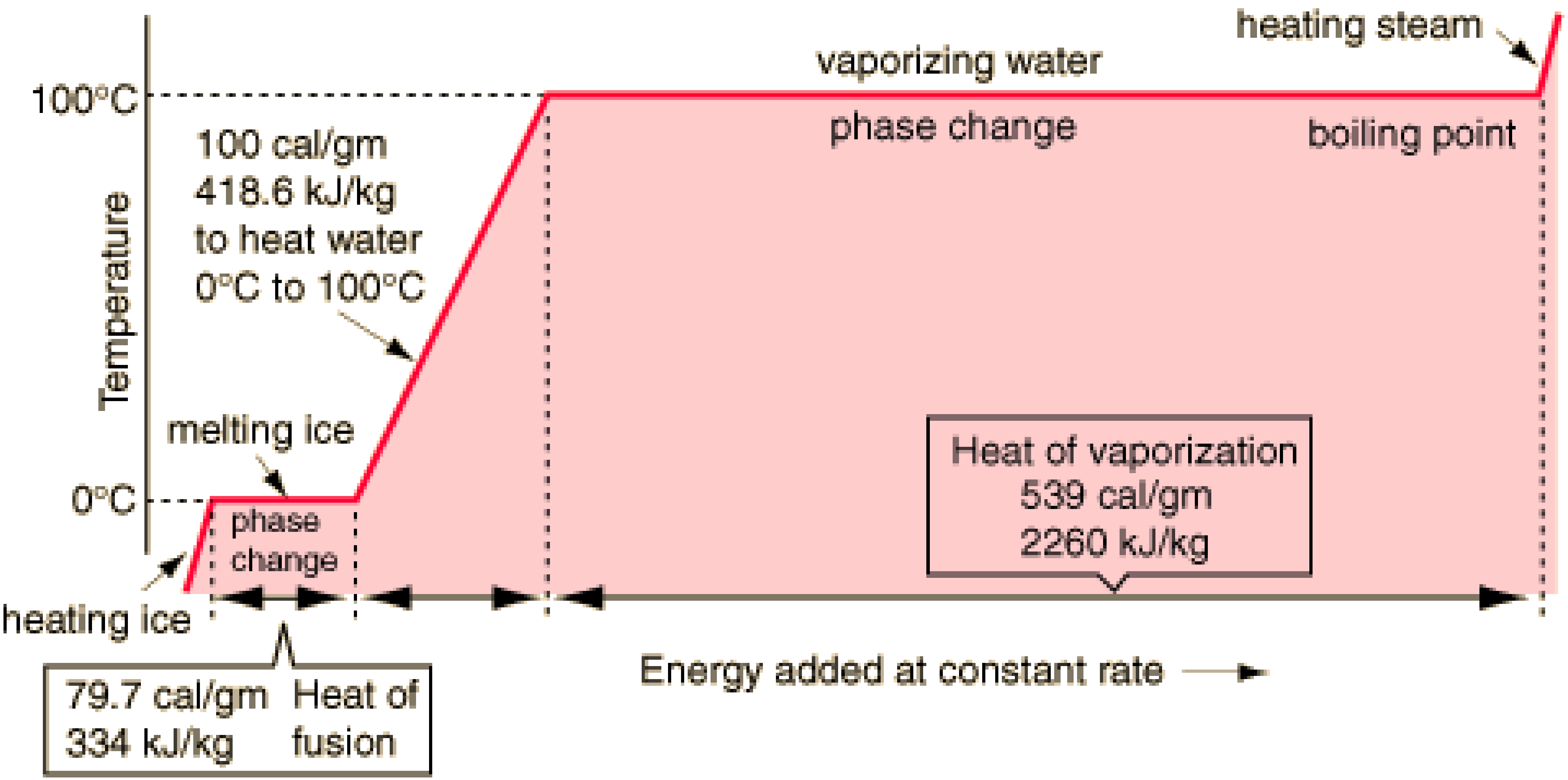
A Phase Change Material (PCM) is a substance with a high heat of fusion which, melting and solidifying at certain temperatures, is capable of storing or releasing large amounts of energy.

DIFFERENT SOLID PHASES OF CARBON

Graphite

Diamond

PHASE IS A FUNCTION OF TEMPERATURE



SPECIFIC HEAT & LATENT HEAT

Specific Heat

$$Q = m\,c\,\Delta T$$

Energy (J)

Mass (g)

Specific Heat Capacity (J/gK)

Change in Temperature (K)

Latent Heat

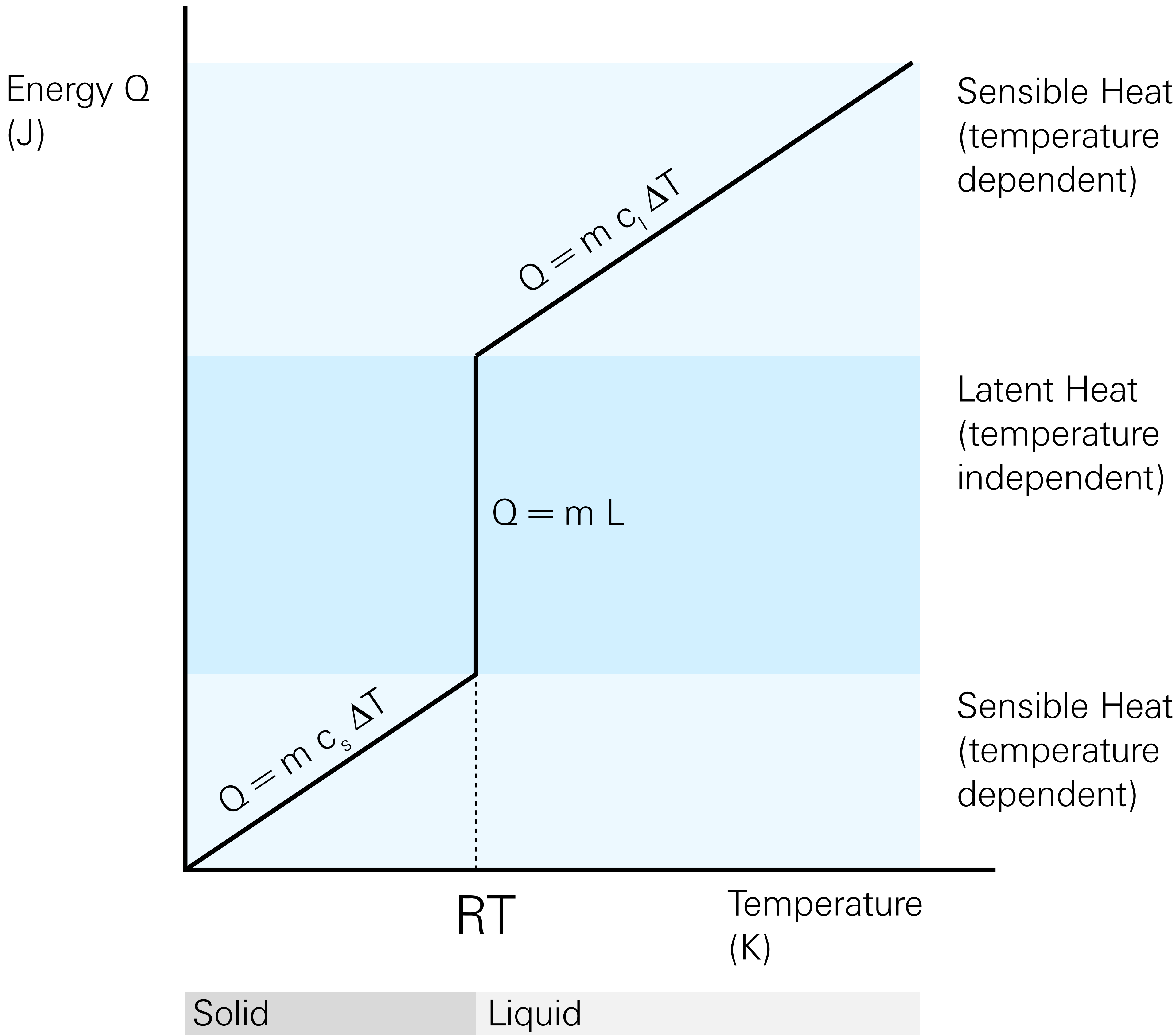
$$Q = m\,L$$

Energy (J)

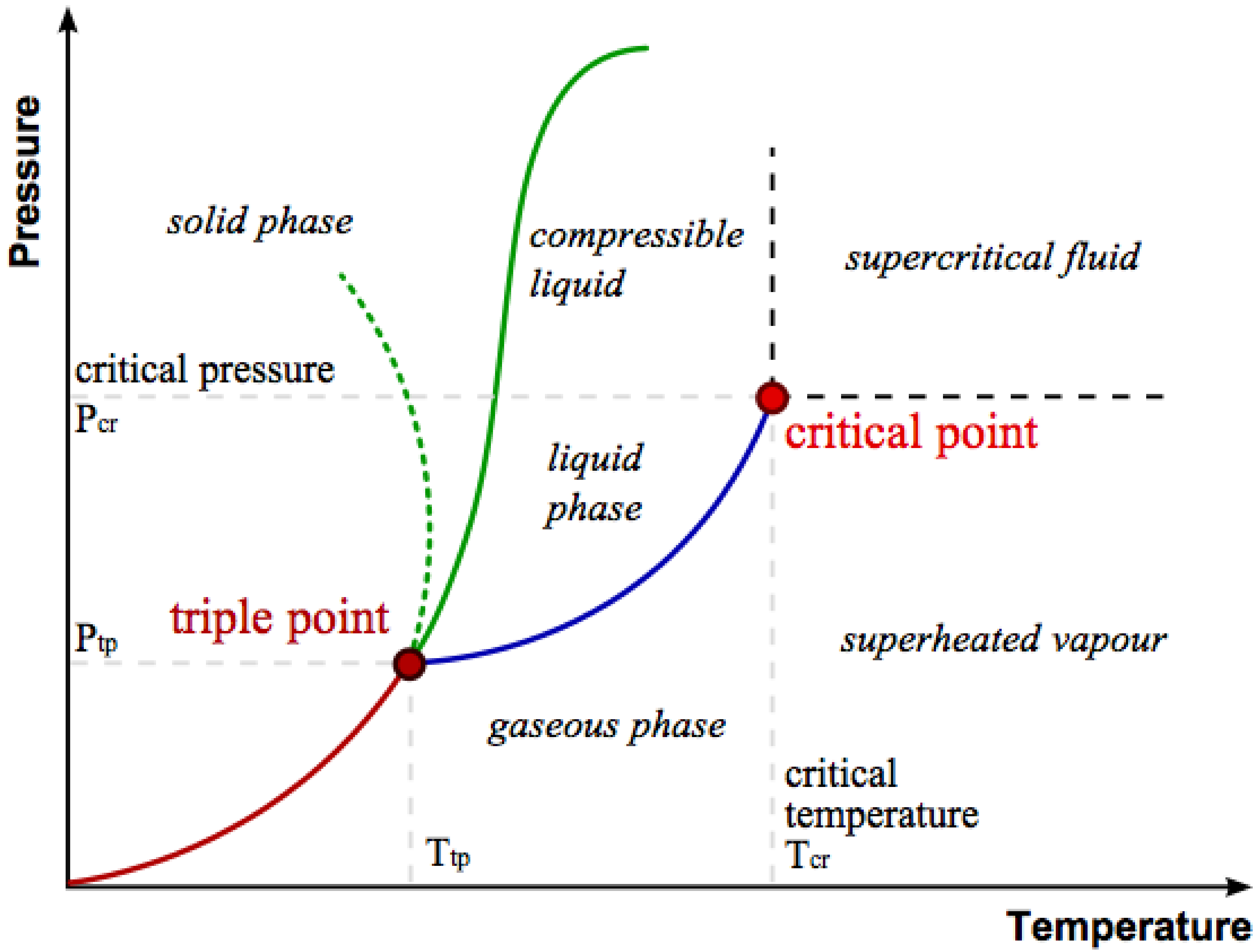
Mass (g)

Specific Latent Heat (J/g)

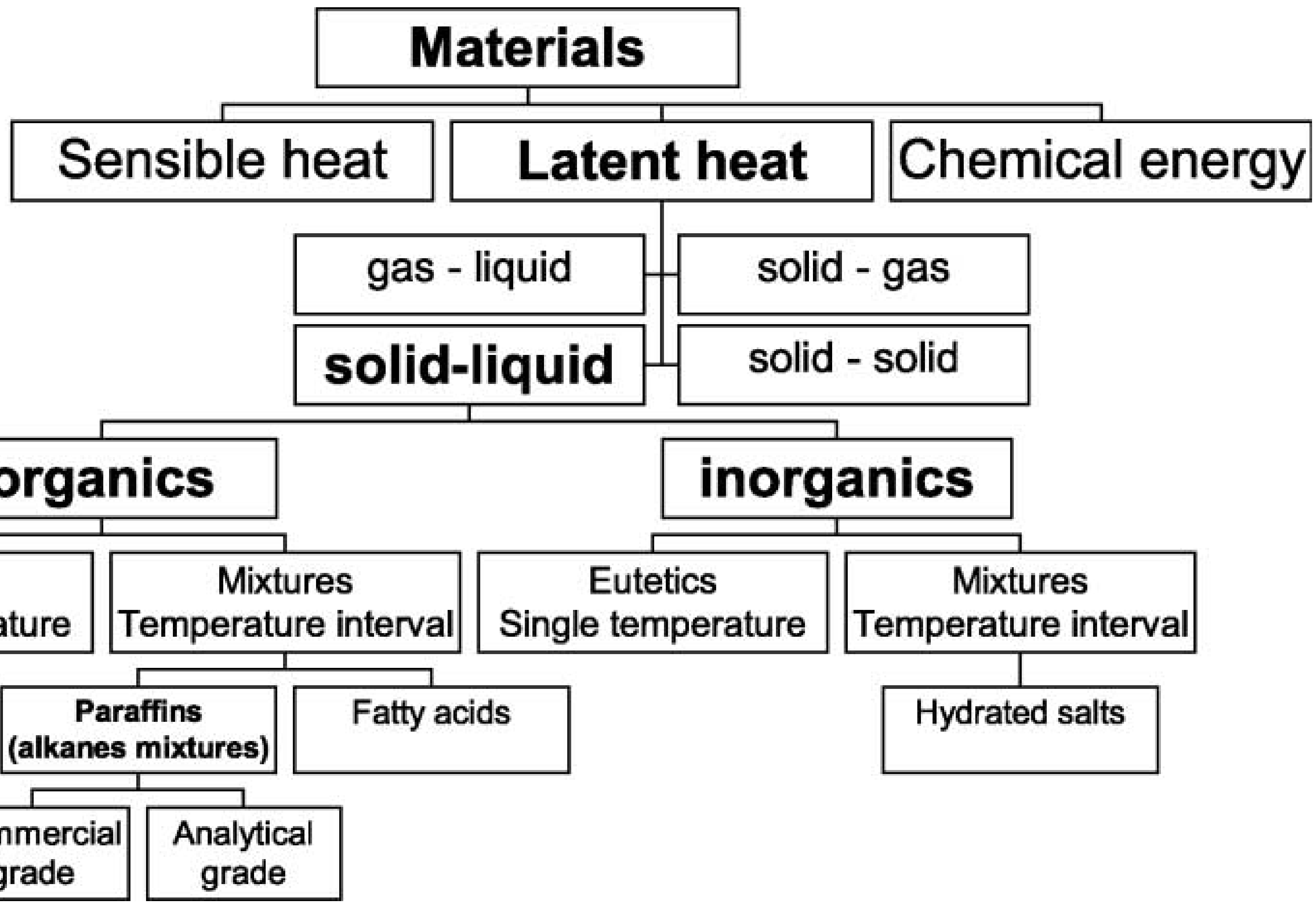
PHASE CHANGE DIAGRAM



PHASE IS A FUNCTION OF PRESSURE



CLASSIFICATION



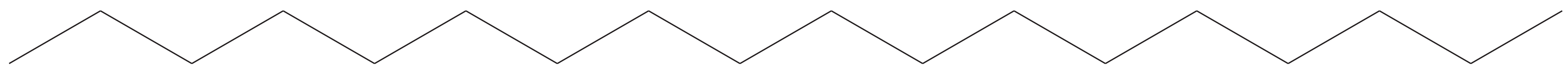
DESIRABLE CHARACTERISTICS

Thermal properties	Physical properties	Chemical properties	Economic factors
Phase change temperature suitable to the desired operating range	High density	Chemical stability	Available in large quantities
High latent heat per unit mass	Low density variation during phase change	No chemical decomposition	Inexpensive
High specific heat	Little or no supercooling during freezing	Compatibility with container materials	
High thermal conductivity in both solid and liquid phases		Non-poisonous, non-inflammable and non-explosive	

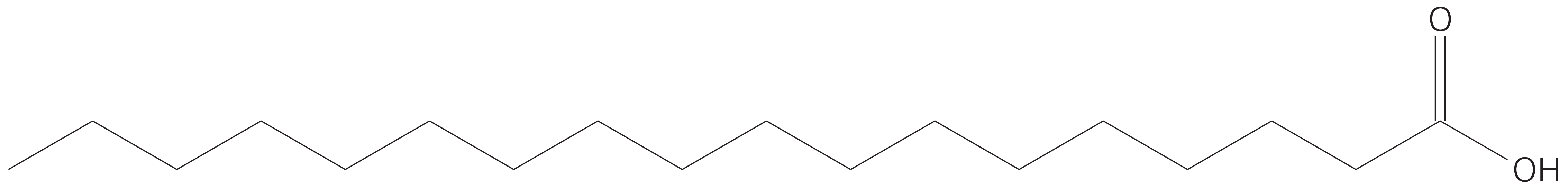
Compound	Melting temperature (°C)	Heat of fusion (kJ/kg)	Thermal conductivity (W/m K)	Density (kg/m^3)
Paraffin C_{14}	4.5 [1]	165 [1]	n.a.	n.a.
Paraffin C_{15}–C_{16}	8 [1]	153 [1]	n.a.	n.a.
Polyglycol E400	8 [4,11]	99.6 [4,11]	0.187 (liquid, 38.6 °C) [4,11] 0.185 (liquid, 69.9 °C) [11]	1125 (liquid, 25 °C) [4,11] 1228 (solid, 3 °C) [4,11]
Dimethyl-sulfoxide (DMS)	16.5 [28]	85.7 [28]	n.a.	1009 (solid and liquid) [28]
Paraffin C_{16}–C_{18}	20–22 [29]	152 [29]	n.a.	n.a.
Polyglycol E600	22 [4,11]	127.2 [4,11]	0.189 (liquid, 38.6 °C) [4,11] 0.187 (liquid, 67.0 °C) [11]	1126 (liquid, 25 °C) [4,11] 1232 (solid, 4 °C) [4,11]
Paraffin C_{13}–C_{24}	22–24 [1]	189 [1]	0.21 (solid) [1]	0.760 (liquid, 70 °C) [1] 0.900 (solid, 20 °C) [1]
1-Dodecanol	26 [9]	200 [9]	n.a.	n.a.
Paraffin C_{18}	28 [1] 27.5 [30]	244 [1] 243.5 [30]	0.148 (liquid, 40 °C) [30] 0.15 (solid) [1] 0.358 (solid, 25 °C) [30]	0.774 (liquid, 70 °C) [1] 0.814 (solid, 20 °C) [1]
1-Tetradecanol	38 [9]	205 [9]		
Paraffin C_{16}–C_{28}	42–44 [1]	189 [1]	0.21 (solid) [1]	0.765 (liquid, 70 °C) [1] 0.910 (solid, 20 °C) [1]
Paraffin C_{20}–C_{33}	48–50 [1]	189 [1]	0.21 (solid) [1]	0.769 (liquid, 70 °C) [1] 0.912 (solid, 20 °C) [1]
Paraffin C_{22}–C_{45}	58–60 [1]	189 [1]	0.21 (solid) [1]	0.795 (liquid, 70 °C) [1] 0.920 (solid, 20 °C) [1]
Parffin wax	64 [4,11]	173.6 [4,11] 266 [6]	0.167 (liquid, 63.5 °C) [4,11] 0.346 (solid, 33.6 °C) [4,11]	790 (liquid, 65 °C) [4,11] 916 (solid, 24 °C) [4,11]

ORGANIC PCM SUBSTANCES

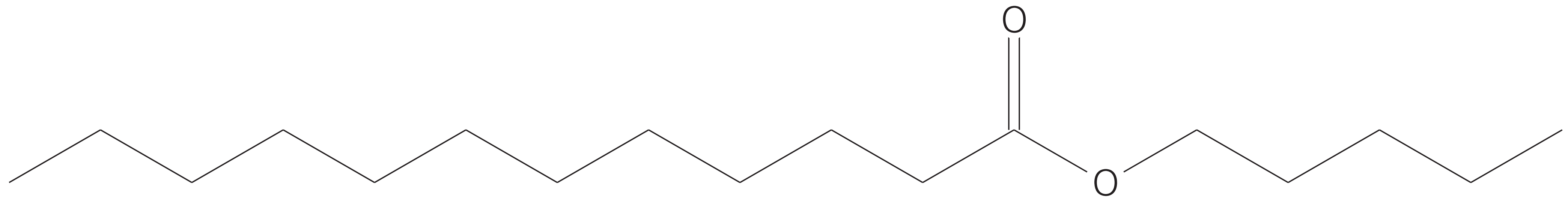
Paraffin Waxes



Carboxylic Acids

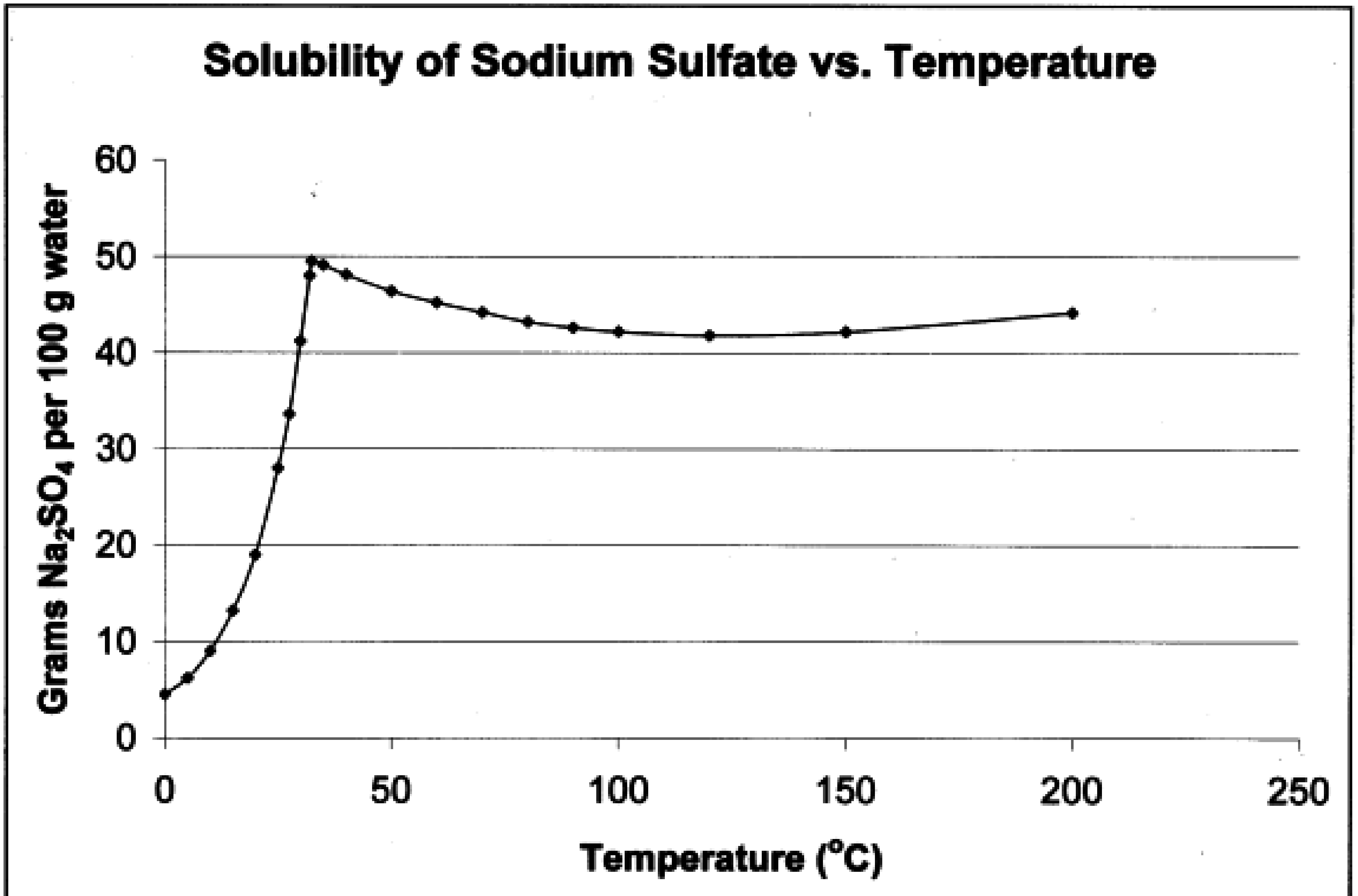


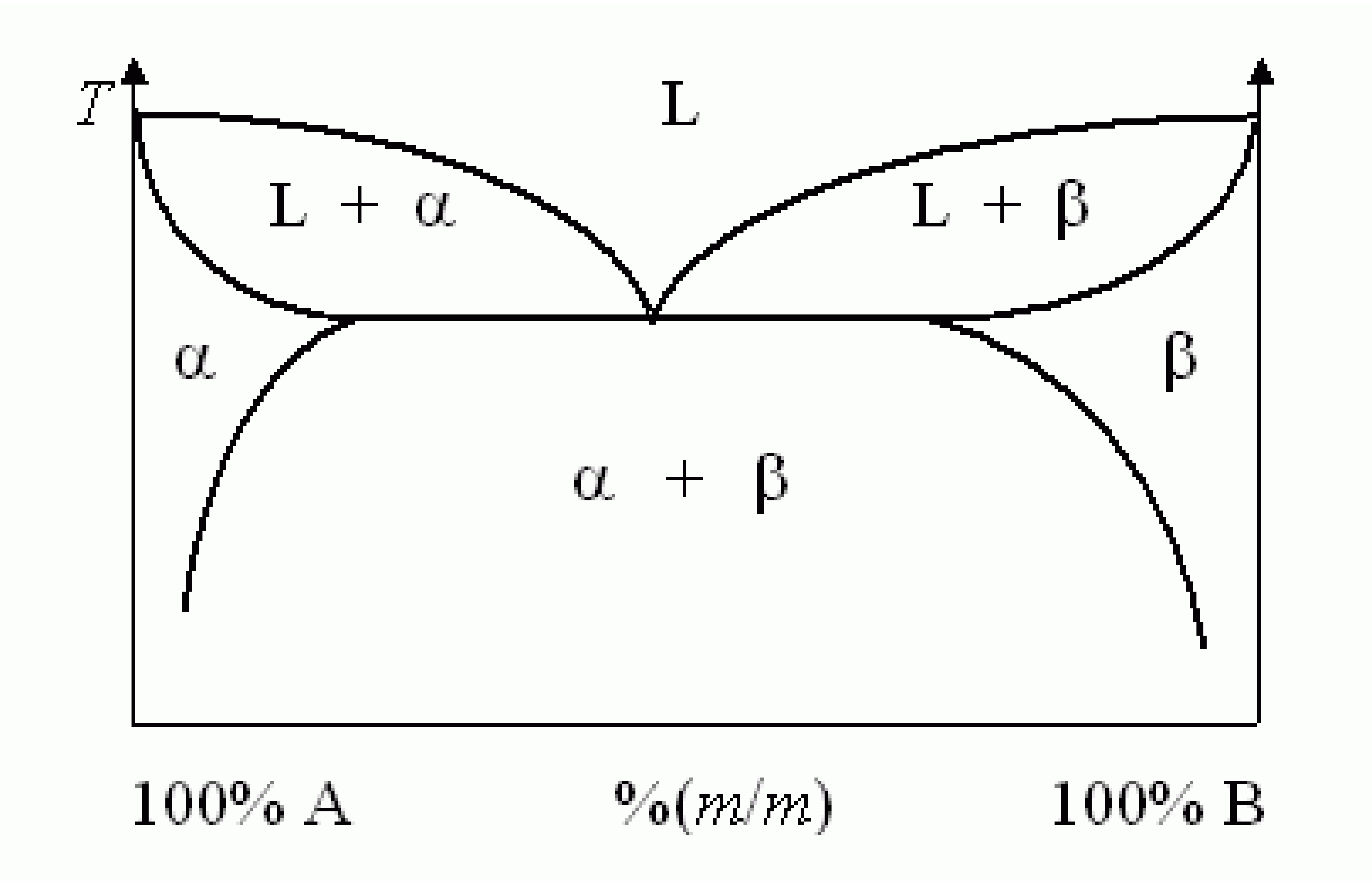
Esters



Compound	Melting temperature (°C)	Heat of fusion (kJ/kg)	Thermal conductivity (W/m K)	Density (kg/m^3)
H_2O	0 [1,5]	333 [1]	0.612 (liquid, 20 °C) [1]	998 (liquid, 20 °C) [1]
		334 [5]	0.61 (30 °C) [5]	996 (30 °C) [5]
				917 (solid, 0 °C) [1]
$Mn(NO_3)_2 \cdot 6H_2O$	25.8 [18]	125.9 [10]	n.a.	1738 (liquid, 20 °C) [10]
				1728 (liquid, 40 °C) [10]
				1795 (solid, 5 °C) [10]
$CaCl_2 \cdot 6H_2O$	29 [4,11]	190.8 [4,11]	0.540 (liquid, 38.7 °C) [4,11]	1562 (liquid, 32 °C) [4,11]
	29.2 [7]	171 [1,9]	0.561 (liquid, 61.2 °C) [11]	1496 (liquid) [1]
	29.6 [6]	174.4 [12]	1.088 (solid, 23 °C) [4,11]	1802 (solid, 24 °C) [4,11]
	29.7 [1,9]	192 [6]		1710 (solid, 25 °C) [1]
	30 [8]			1634 [12]
	29–39 [12]			1620 [6]
$LiNO_3 \cdot 3H_2O$	30 [6]	296 [6]	n.a.	n.a.
$Na_2SO_4 \cdot 10H_2O$	32.4 [1,7,9]	254 [1,9]	0.544 [1]	1485 (solid) [1]
	32 [13]	251.1 [12]		1458 [12]
	31–32 [12]			
$Na_2CO_3 \cdot 10H_2O$	32–36 [12]	246.5 [12]	n.a.	1442 [12]
	33 [6,7]	247 [6]		
$CaBr_2 \cdot 6H_2O$	34 [4,7,11]	115.5 [4,11]	n.a.	1956 (liquid, 35 °C) [4,11]
				2194 (solid, 24 °C) [4,11]

SODIUM SULFATE DECAHYDRATE SOLUBILITY

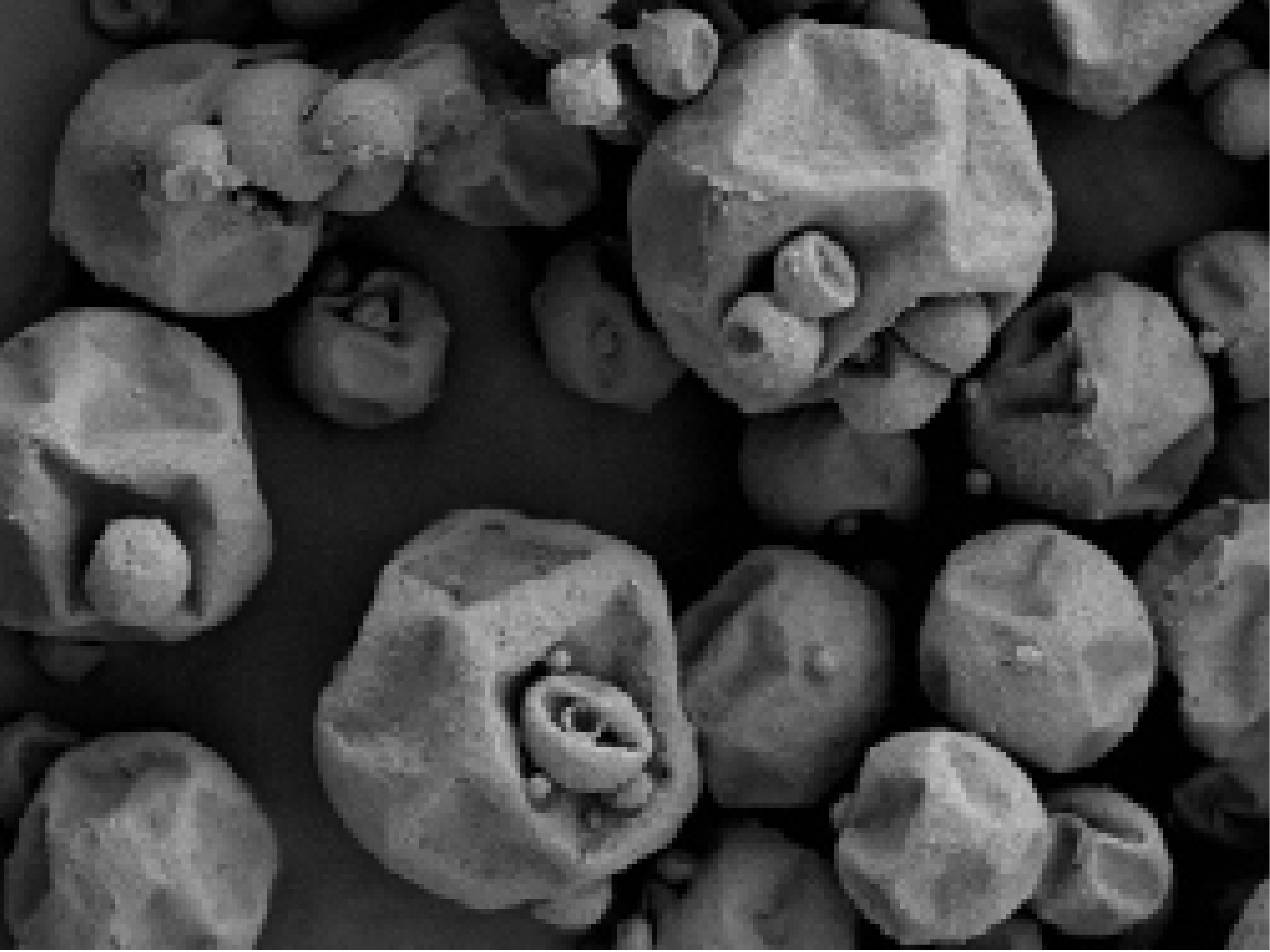



T
L
L + α
L + β
α
β
α + β
100% A
%(m/m)
100% B

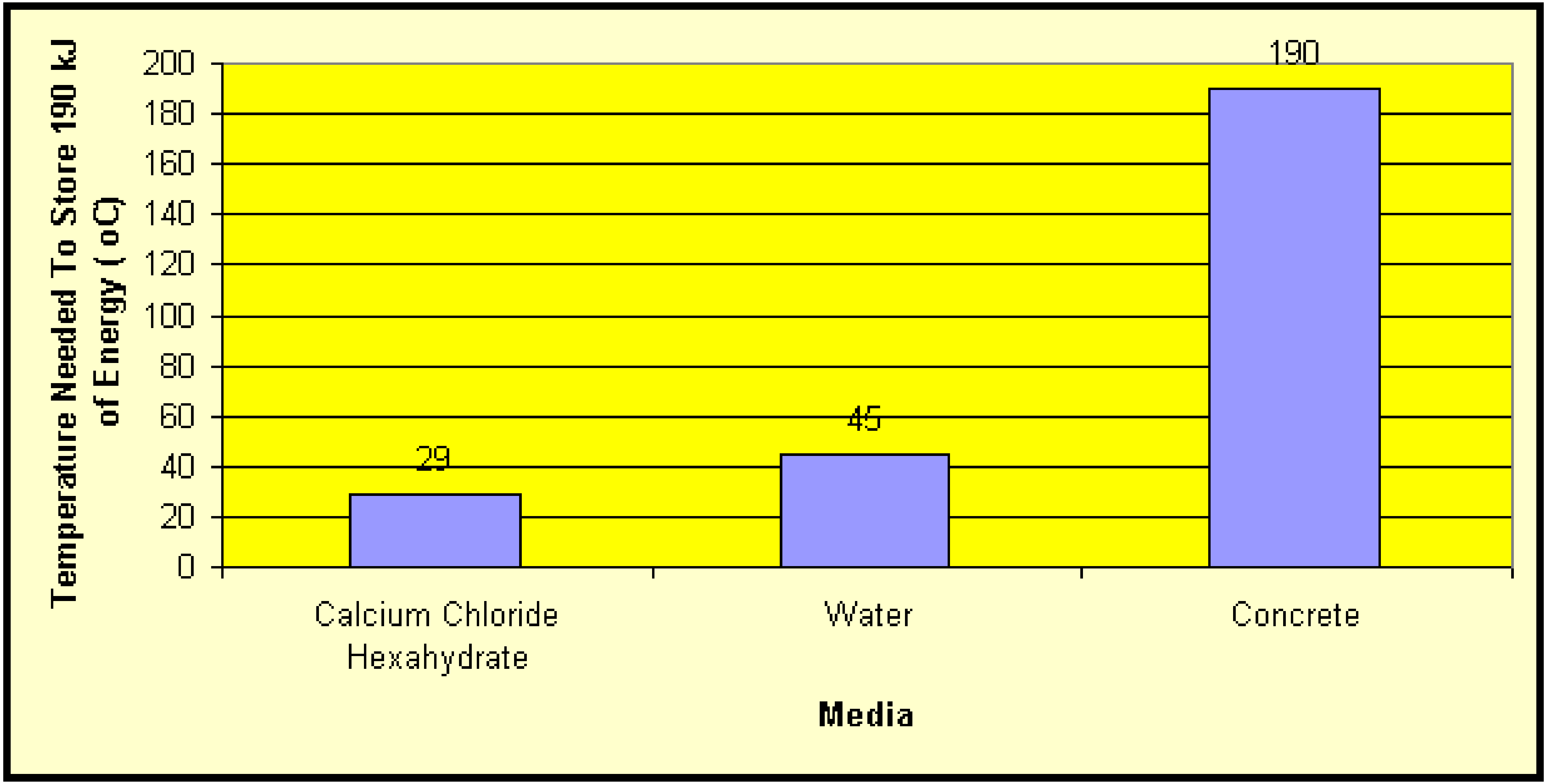
INORGANIC EUTECTIC PCM SUBSTANCES

Compound	Melting temperature (°C)	Heat of fusion (kJ/kg)	Thermal conductivity (W/m K)	Density (kg/m^3)
66.6% $CaCl_2 \cdot 6H_2O$ + 33.3% $MgCl_2 \cdot 6H_2O$	25 [6]	127 [6]	n.a.	1590 [6]
48% $CaCl_2$ + 4.3% NaCl + 0.4% KCl + 47.3% H_2O	26.8 [1,6]	188.0 [6]	n.a.	1640 [6]
47% $Ca(NO_3)_2 \cdot 4H_2O$ + 33% $Mg(NO_3)_2 \cdot 6H_2O$	30 [1]	136 [1]	n.a.	n.a.
60% $Na(CH_3COO) \cdot 3H_2O$ + 40% $CO(NH_2)_2$	31.5 [24] 30 [25]	226 [24] 200.5 [25]	n.a.	n.a.
61.5% $Mg(NO_3)_2 \cdot 6H_2O$ + 38.5% NH_4NO_3	52 [11]	125.5 [11]	0.494 (liquid, 65.0 °C) [11] 0.515 (liquid, 88.0 °C) [11] 0.552 (solid, 36.0 °C) [11]	1515 (liquid, 65 °C) [11] 1596 (solid, 20 °C) [11]
58.7% $Mg(NO_3) \cdot 6H_2O$ + 41.3% $MgCl_2 \cdot 6H_2O$	59 [11] 58 [6]	132.2 [11] 132 [6]	0.510 (liquid, 65.0 °C) [11] 0.565 (liquid, 85.0 °C) [11] 0.678 (solid, 38.0 °C) [11] 0.678 (solid, 53.0 °C) [11]	1550 (liquid, 50 °C) [11] 1630 (solid, 24 °C) [11]
53% $Mg(NO_3)_2 \cdot 6H_2O$ + 47% $Al(NO_3)_2 \cdot 9H_2O$	61 [1]	148 [1]	n.a.	n.a.
14% $LiNO_3$ + 86% $Mg(NO_3)_2 \cdot 6H_2O$	72 [6]	>180 [6]	n.a.	1590 (liquid) [6] 1610 (solid) [6]
66.6% urea + 33.4% NH_4Br	76 [11]	161.0 [11]	0.331 (liquid, 79.8 °C) [11] 0.324 (liquid, 92.5 °C) [11] 0.649 (solid, 39.0 °C) [11] 0.682 (solid, 65 °C) [11]	1440 (liquid, 85 °C) [11] 1548 (solid, 24 °C) [11]
11.8% NaF + 54.3% KF +	449 [26]	n.a.	n.a.	2160 (liquid) [26]

PCM MATERIALS IN BUILDING CONSTRUCTION

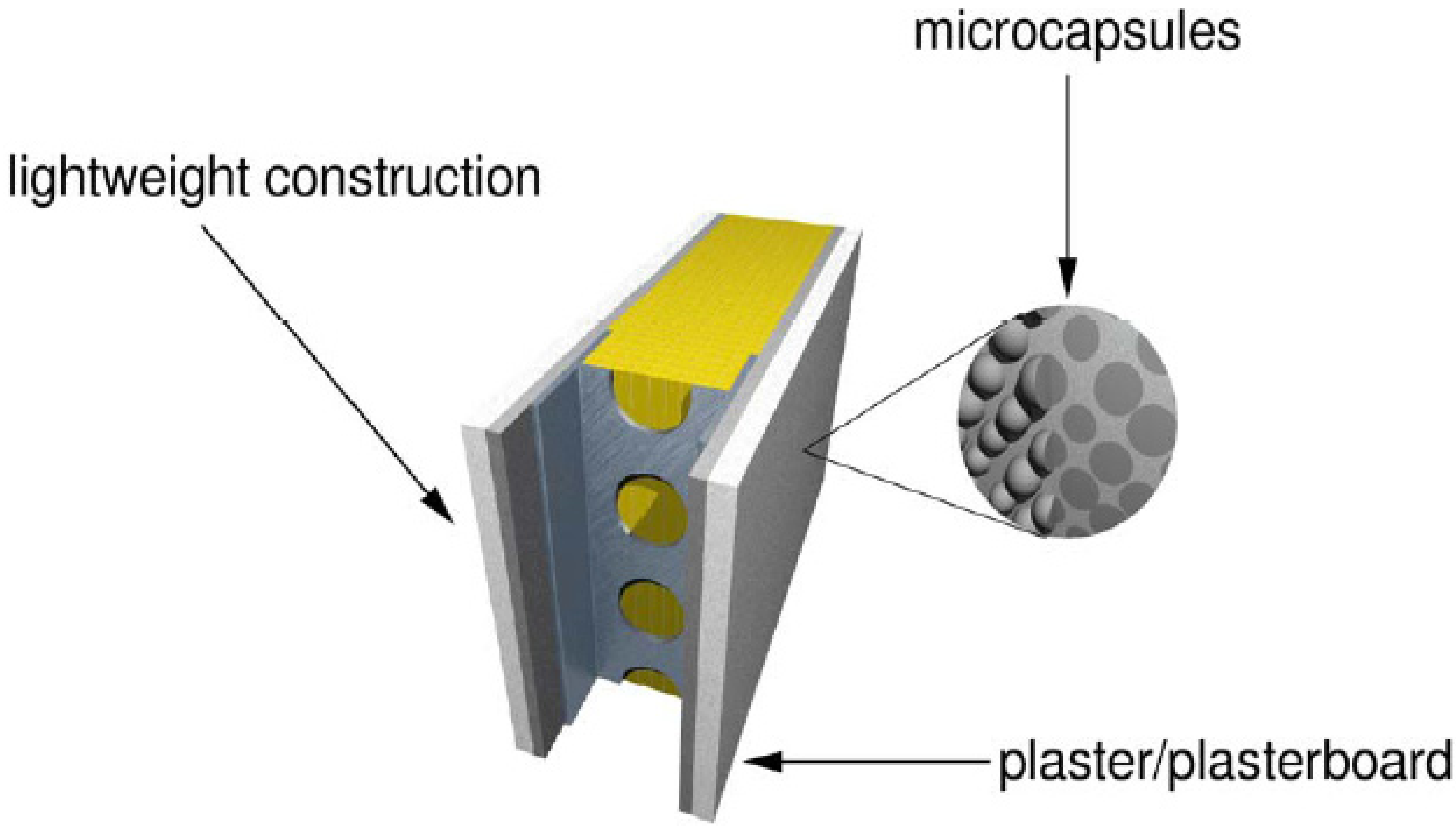


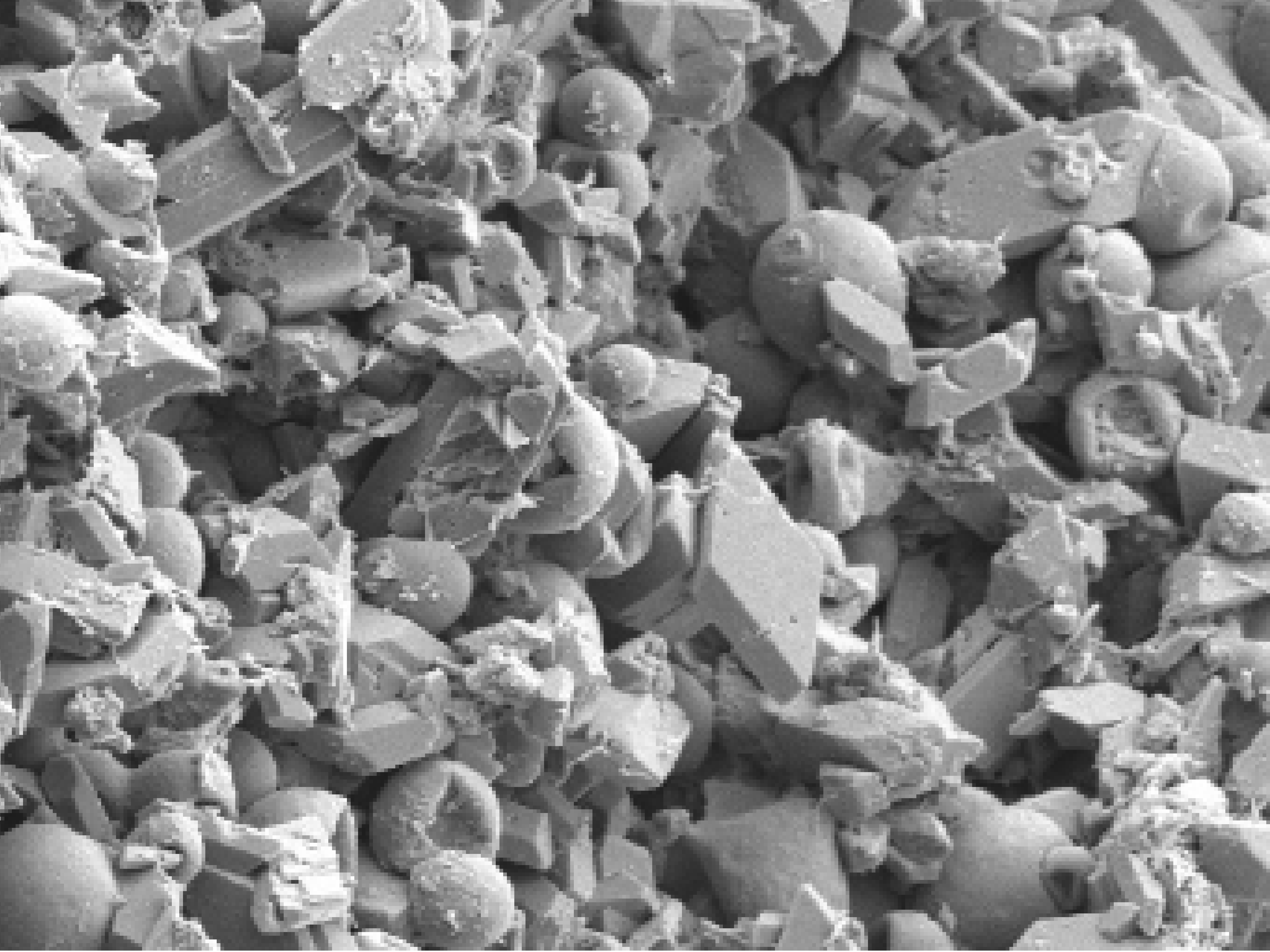
PCM VS. TRADITIONAL THERMAL MASS MATERIALS



CONCRETE IMPREGNATED WITH PCMs

PCMs IN WALLS



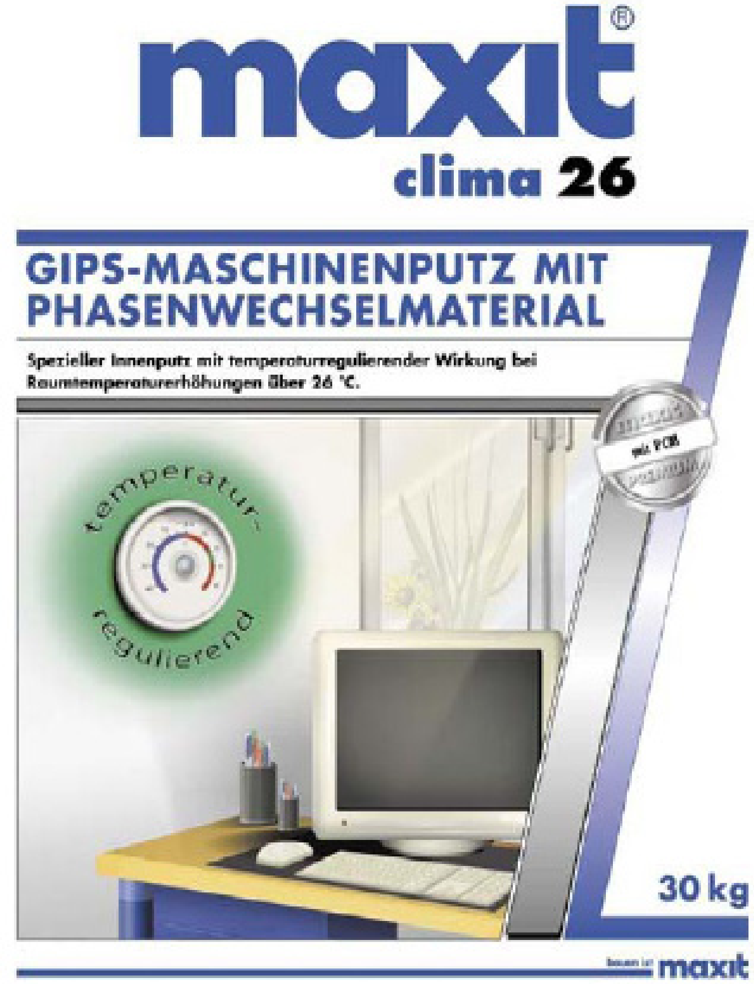


products on the market

two companies selling macro-encapsulated PCM:

Dörken

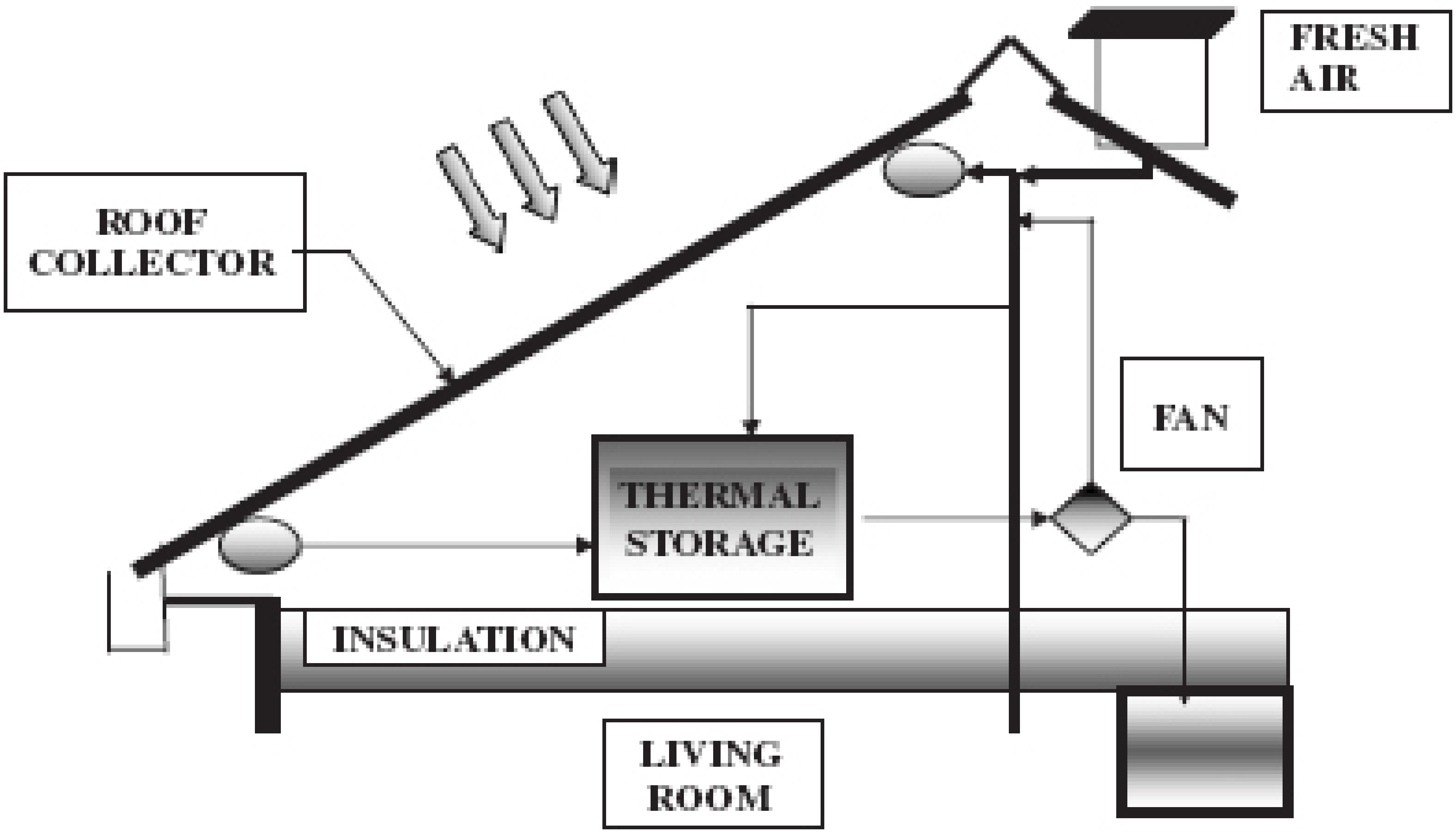
Rubitherm



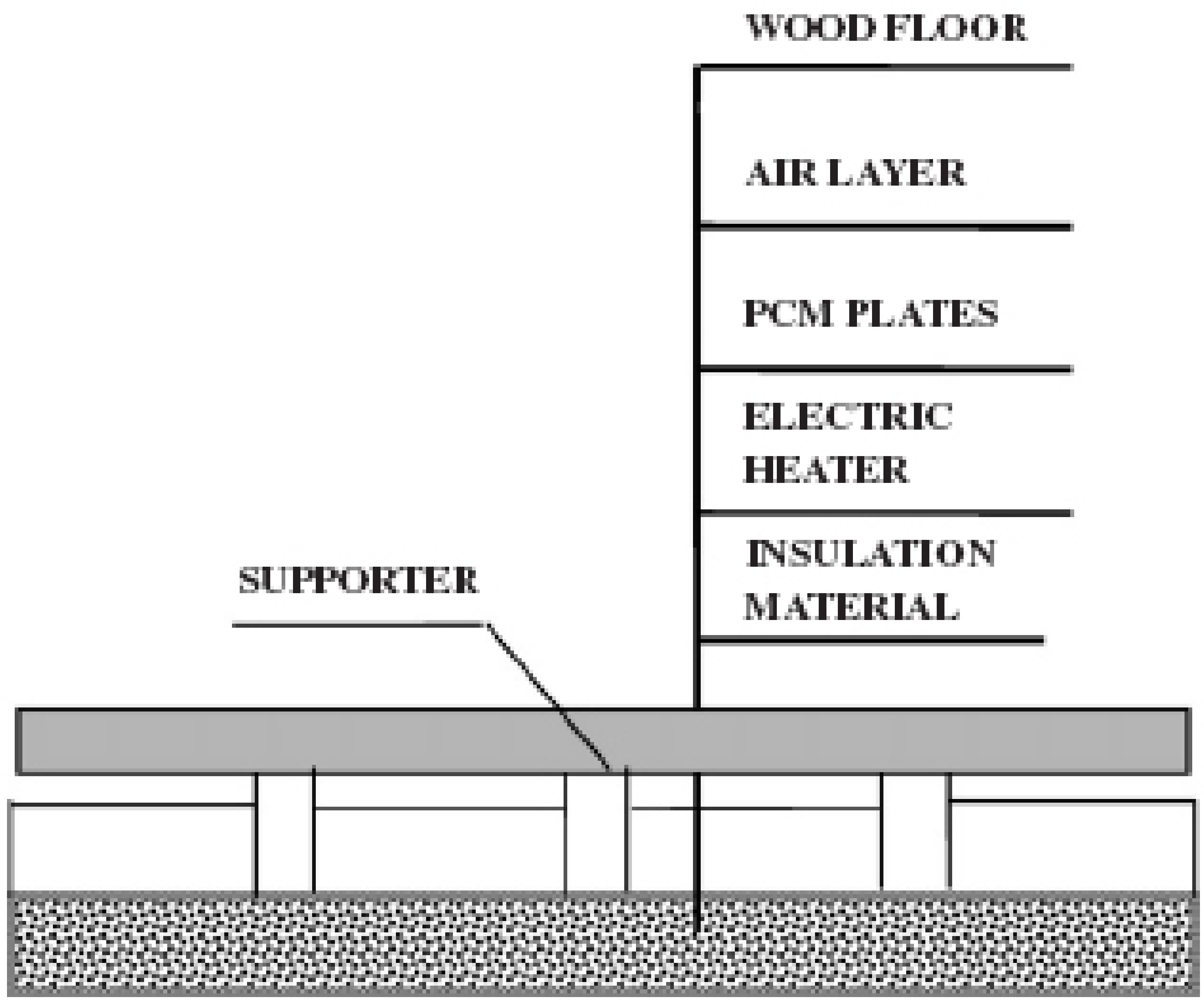
some products based on microcapsules (plaster, plasterboard, dispersion based plaster)

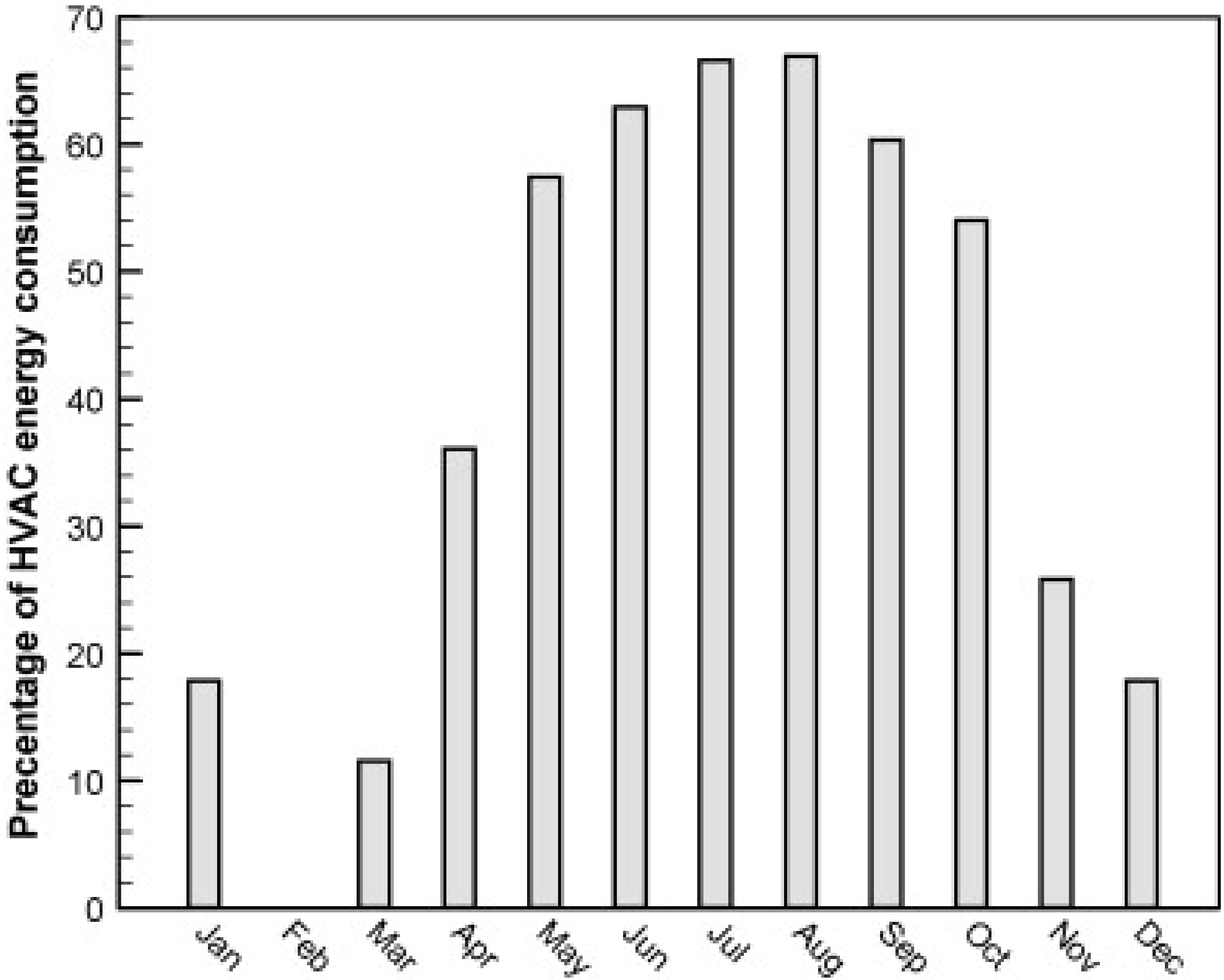
www.micronal.de

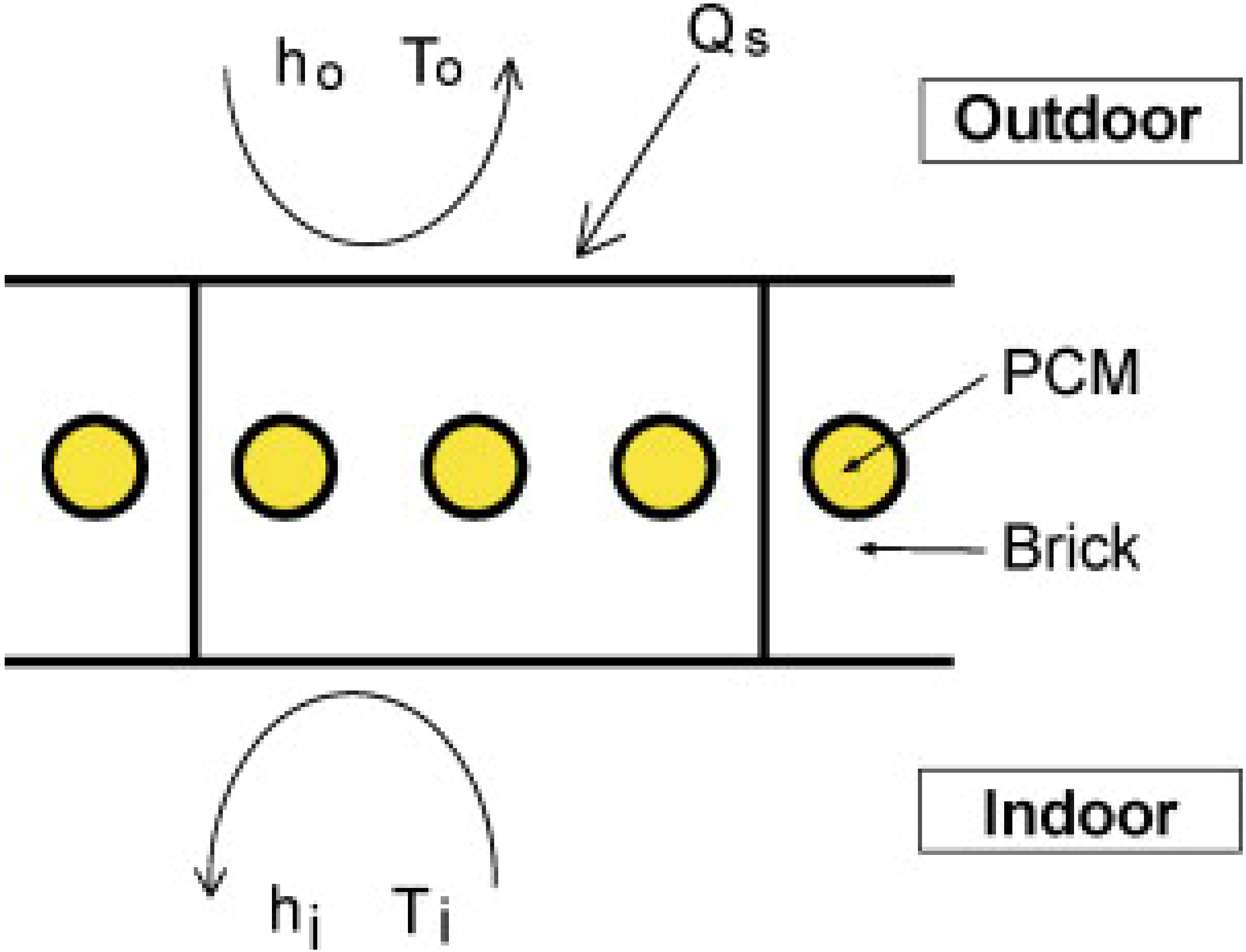
BASF The Chemical Company


FRESH
AIR
ROOF
COLLECTOR
FAN
THERMAL
STORAGE
INSULATION
LIVING
ROOM

FLOORS

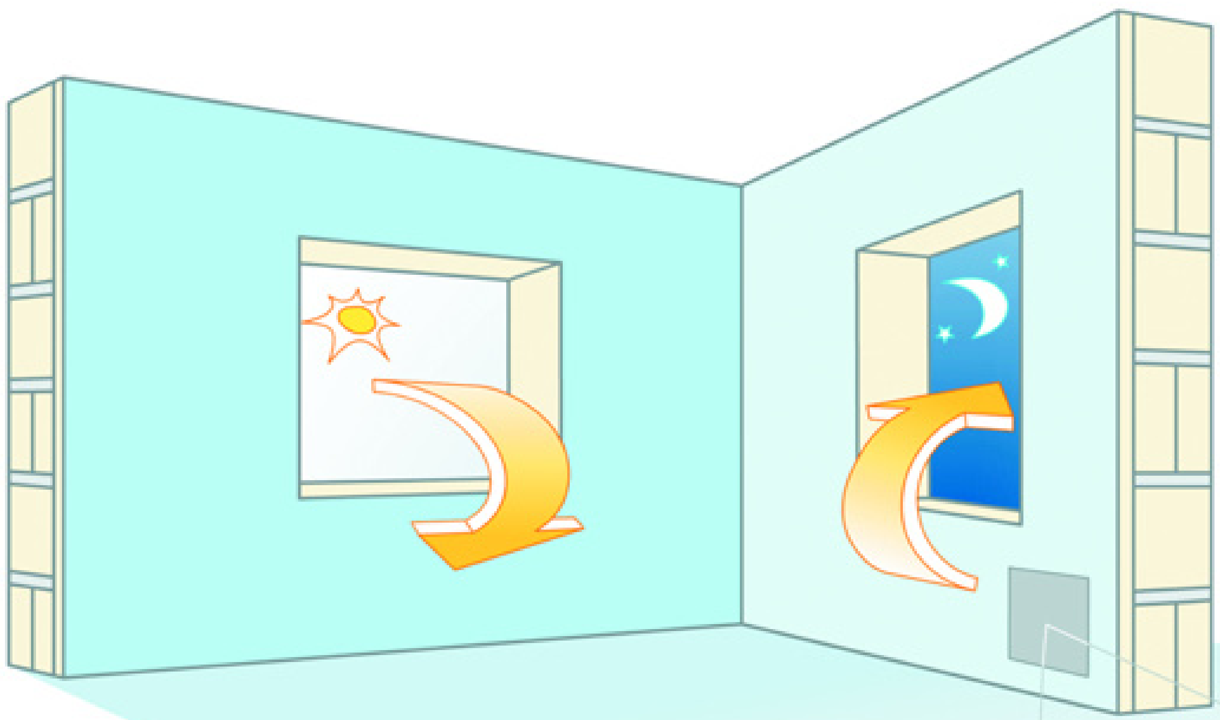

WOOD FLOOR
AIR LAYER
PCM PLATES
ELECTRIC HEATER
INSULATION MATERIAL
SUPPORTER


Precentage of HVAC energy consumption
70
60
50
40
30
20
10
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec



h_o T_o
Q_s
Outdoor
PCM
Brick
Indoor
h_i T_i

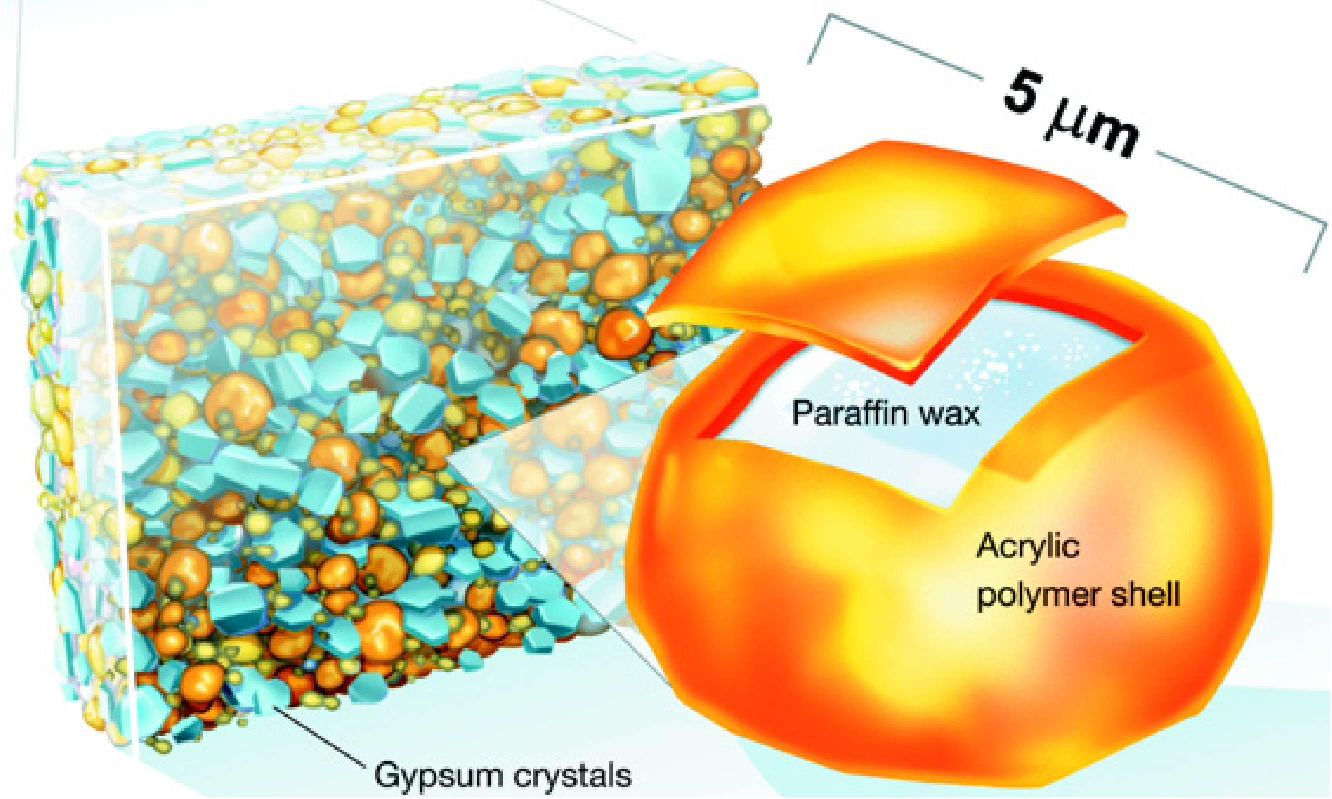
MICRONAL® PCM
THERMAL BUFFER FOR HOT DAYS



- The solar energy incident on the house heats the rooms up. From about 26C onwards, the microencapsulated wax begins to melt and absorbs the excess heat.
- When the temperatures fall during the night, the wax becomes solid again.
  The warmth that is then released can be removed from the room by ventilation.

The Micronal® PCM microcapsules in SmartBoard™ are embedded in a carrier matrix of gypsum.

Encapsulated in a high strength acrylic polymer shell, the wax still retains its heat buffer function even after several decades.

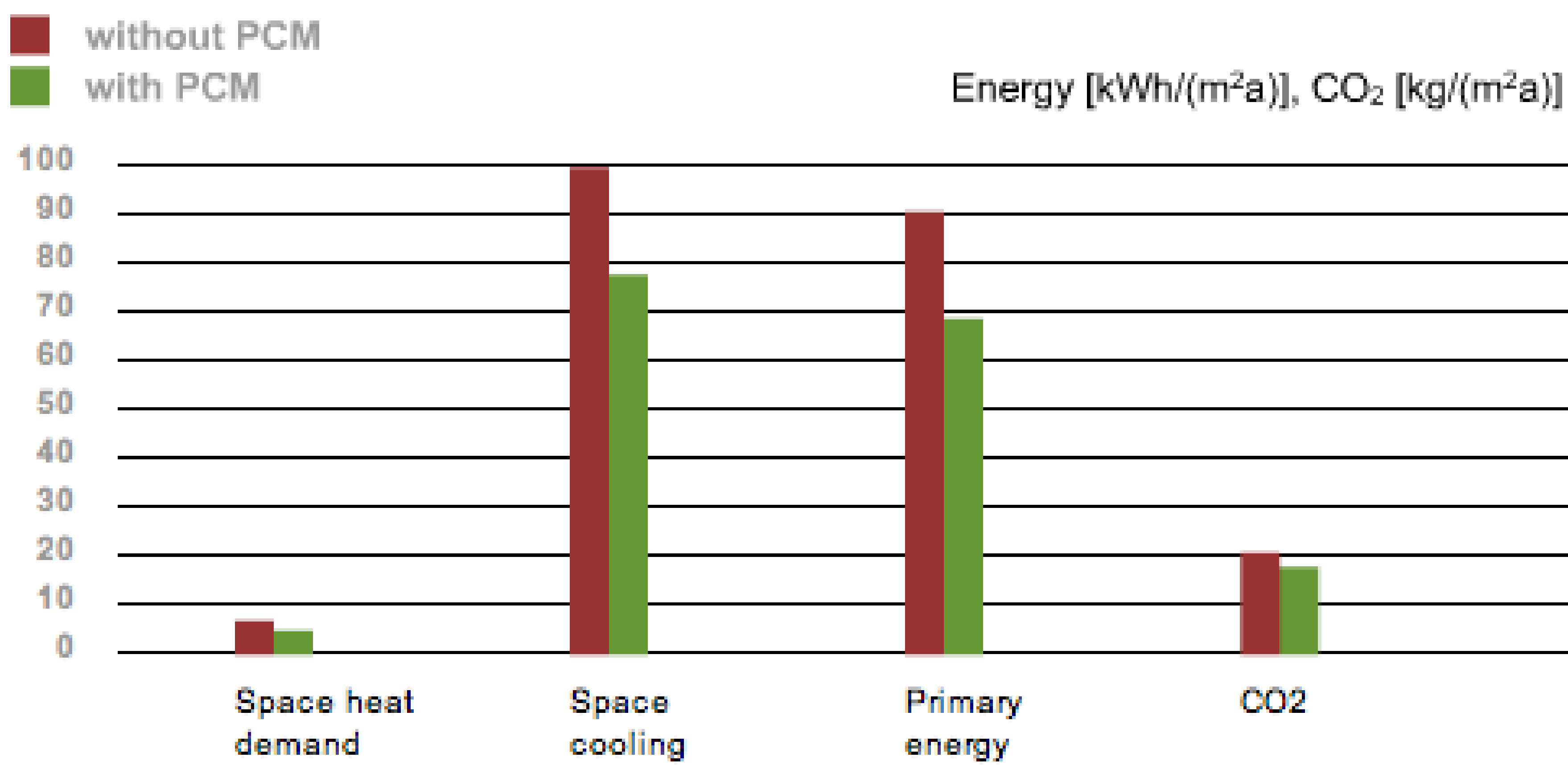


MICRONAL® PCM

Sevilla - Spain

- Warsaw - Poland
- Frankfurt am Main - Germany
- Paris - France
- London - UK
- Rome - Italy
- Sevilla - Spain

(Click on the cities in order to see the study's results)

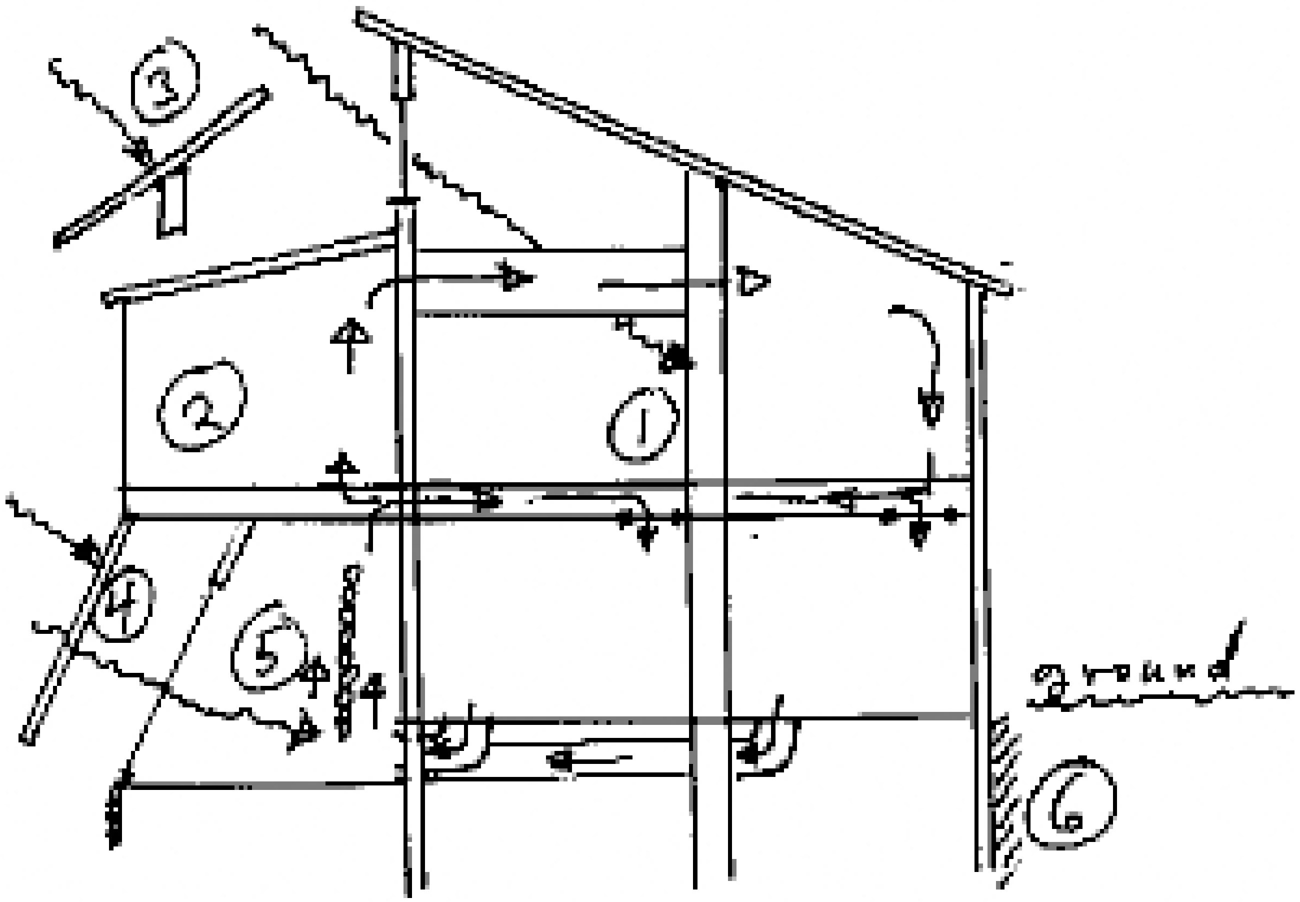


In Rome and Sevilla, with Micronal® PCM SmartBoard by BASF, you can reduce energy consumption and CO2 emissions by more than 20% and drastically increase the building's comfort, both in winter and in summer.

ARCHITECTURAL PRECEDENTS

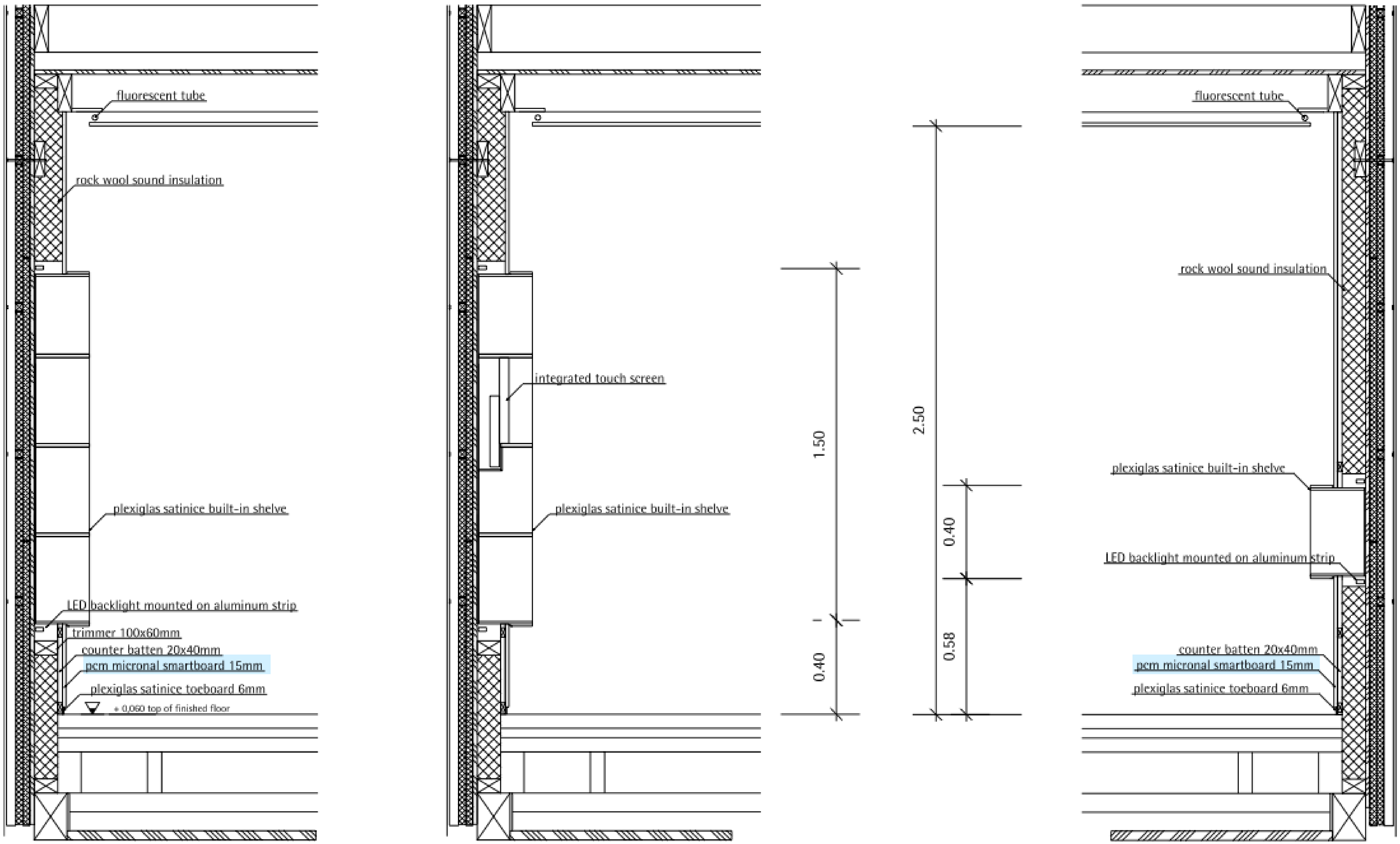
DAVID ALLAN SOLAR HOME

GLAUBER'S SALT CHAMBER

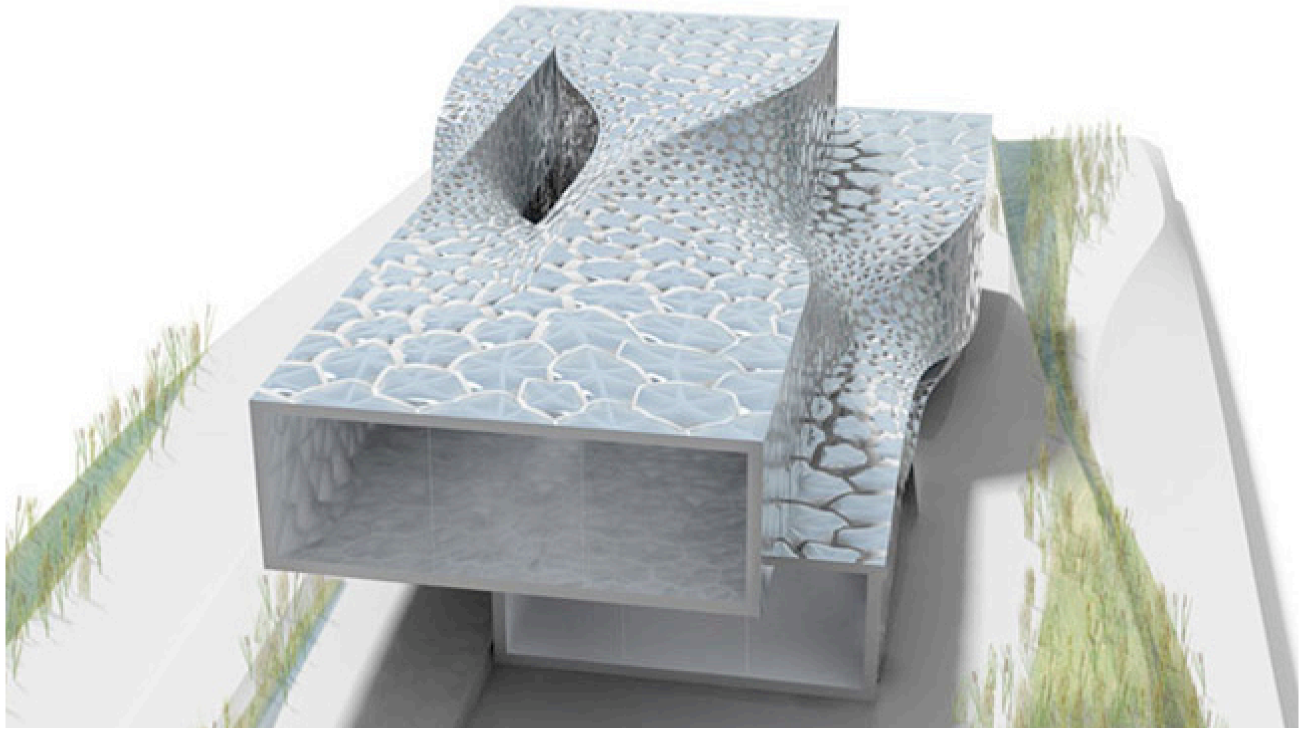


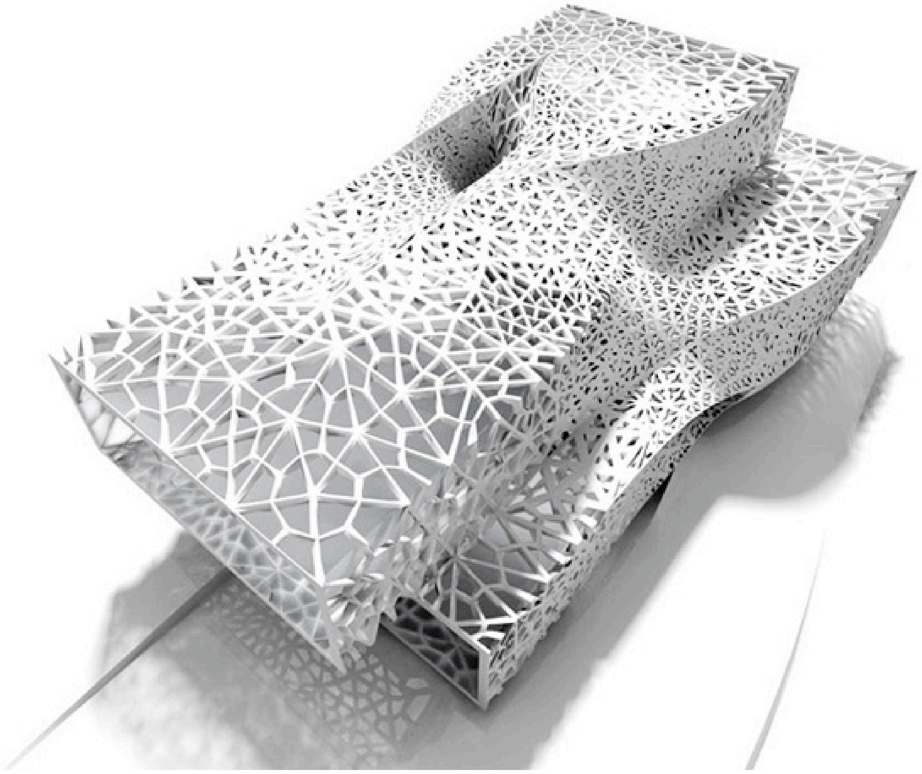
TECHNISCHE UNIVERSITÄT DARMSTADT ENTRY
SOLAR DECATHLON 2007 WINNER

TECHNISCHE UNIVERSITÄT DARMSTADT ENTRY
WALL SECTIONS



IWAMOTO SCOTT
JELLYFISH HOUSE





HIGH-PERFORMANCE FASHION AND SMART MATERIALS

THE COOL VEST

THE COOL VEST

CoolPack Technology | How the Vest Works

Wicking fabric carries body heat released as perspiration away from the body toward the PCM-filled packs lining the garment.

CoolPacks solidify at 59°F (15°C) and absorb body heat until saturated.

Insulation located at the exterior of the jacket minimizes absorption of ambient heat.

CoolPack Technology | Benefits

Helps maintain a Safe Body Core Temperature.

Reduces chances of heat stress—heat stroke and other job site injuries.

Increases Alertness and Production Capabilities 22%–37%.

Decreases reaction time improves safety when operating machinery.

Maintains a constant 59°F (15°C) temperature. Because the temperature range of the packs (59°F) is well above the typical dew point, the packs will not condense and will remain dry against the body.

Recharges in 20 minutes and last up to 2.5 hours, based on average workload and individual metabolic rate, in a 100° F (38°C) environment, and can be recharged indefinitely.

The typical weight of the jacket is 3 pounds for a 100°F product and 9 pounds for a 125–130°F product.

CoolPack Technology | Users

The Cool Jackets and Cool Vest were designed for the industrial safety market. However their use has expanded to include Hazmat Teams, Foundries, under Bunker Gear and Military Flak Jackets, Costume Characters and by workers required to wear Chemical or Biological protective clothing.


1
3
2


Passive Cooling
www.climator.com